RESEARCH HIGHLIGHTS

Technical Series 00-134

THE RENOVATION OF AN APARTMENT BUILDING WITH SOLID MASONRY WALLS

Introduction

In 1996, a four-storey, 30-unit, 86-year-old, apartment building located in Prince Albert, Saskatchewan was completely gutted and renovated. The project attracted the attention of the Research Division of Canada Mortgage and Housing Corporation as the renovation called for the addition of interior insulation to the solid masonry (clay brick) walls of the building. This practice was, and continues to be, contentious due to suspicions that it adversely affects the durability of solid masonry walls by increasing the risk of freeze-thaw cycles, interior wall condensation and cyclic thermal stresses. Consequently, solid masonry buildings are often left uninsulated during renovations at the expense of energy efficiency and occupants' comfort. The Prince Albert building represented an opportunity for CMHC to initiate a research project to document the renovation of a solid masonry building and to monitor and assess the performance of the retrofitted masonry walls and other aspects of the renovated building over the course of a year.

Research Program

The research program was multifaceted and included the following tasks:

1. Assessment of the potential for exterior wall rain penetration of the masonry walls and the development of a rain penetration and interior moisture control strategy.

2. Monitoring of the heat, air and moisture conditions at various locations within the retrofitted exterior wall sections to assess performance.

3. Monitoring of the energy consumption, indoor air quality and ventilation system performance of the building over the first post-renovation year.

Findings

After approximately 1½ years of monitoring, the renovation of the building appears to have been successful. The findings of each research program area are as follows:

Rain Penetration - Interior Moisture Control

A spray test was performed on the building prior to the renovation to assess the potential for water penetration of the solid masonry (clay brick) walls due to wind-driven rain. The test found the walls to be extremely susceptible to rain penetration. The building owners were advised that a rain penetration control strategy would be necessary to protect the walls from

moisture-related damage. The renovation plan was altered to include the installation of a protective layer of stucco on the side and rear elevations of the building. The front elevation was not covered due to heritage and aesthetic considerations, however, mortar joint repointing was recommended. Laboratory stucco adhesion and cracking tests were performed to identify the properties of the stucco required to ensure long-term performance. It was determined that a polyvinyl acetate emulsion adhesive primer was required to ensure uniform stucco adhesion to the masonry. Prior to the application of the stucco, it was recommended that fibreglass reinforcing mesh be installed over cracks in the masonry substrate and expanded metal mesh lathe be applied around all window openings. Construction joint locations were also determined.

Plans were also developed to protect the wall system from interior moisture sources. Special details were created to ensure air and vapour barrier continuity around windows and through floor platforms. A balanced supply air-exhaust air ventilation system was designed and installed to mitigate occupant-related moisture generation and to ensure a continuous supply of fresh air to all areas of the building. A supply air system provides fresh air to the common corridor on each floor while exhaust air is drawn from all apartments by continuously operating central exhaust fans. Exhaust grilles, connected to the exhaust air system, were provided in all rooms to exhaust stale air from, and to induce fresh air into, all areas of the building.

Post-Retrofit Performance of the Masonry Walls

The performance of the retrofitted wall structure was assessed by a monitoring program devised to record heat, air and moisture conditions at various points through the wall section. Moisture contents of wood joists in the attic space were also monitored. Rain wetting patterns were recorded to determine the relation of rain to the conditions recorded through the wall sections. Local weather conditions and indoor relative humidity and temperature were also tracked. Conditions were monitored in six wall locations representative of all elevations and floor levels. The instrumentation was connected to a multi-channel data logger located in the building, which accumulated data on 30-minute intervals for 15 months. The findings of the monitoring program include:

- The protective stucco layer was successful in reducing the amount of water penetration into the wall assembly. Rain penetration through wall sections that were not stuccoed was evident.

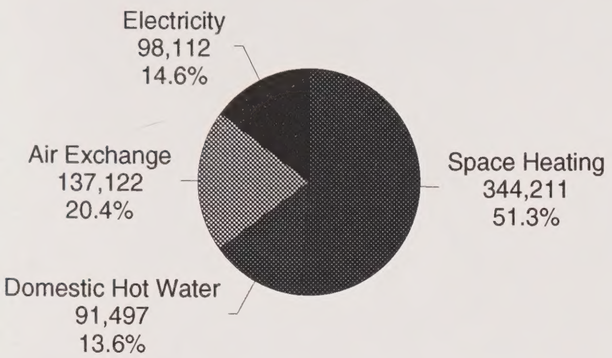
- The original solid masonry wall structure (which has a layer of cement parging on the interior) was responsible for a significant proportion of the overall final airtightness of the renovated building.

- The addition of insulation (RSI 3.5) on the interior of the masonry walls subjected the masonry walls to outdoor temperature and moisture conditions. The solid masonry walls tended to dampen the short term oscillations in cavity humidity when compared to outdoor conditions.

Energy Consumption

The energy consumption of the renovated building was compared to pre-renovation use. Despite the installation of upgraded thermal insulation, air barrier system, radiant floor heating, and new windows, the building consumed 670,942 kWhe (399 kWhe/m^2 or 0.061 kWhe/m^2/degree day). Approximately 20% more natural gas was consumed in the first year after the renovation than was used in the previous year. The installation of a high capacity, continuously operating ventilation system, increased occupancy, and occupants' preference for relatively high indoor temperatures are likely the primary causes of the increased energy consumption. However, when the energy consumption of the building is normalized to building area and degree day location, it is found to be comparable to other, recently constructed, mid-rise residential buildings in Canada.

Figure 1: Annual Post-Retrofit Energy Consumption (kWhe)



Ventilation System Performance and Indoor Environment

The continuously operating supply and exhaust air systems serve every habitable room in the building. As a result, the indoor air quality within the building is quite good (Table 1).

Table 1: Post-retrofit Indoor Environment Indicators (mid-winter)

Suite	HCHO (ppm)	Particulates (μg/m^3)	TVOC mg/m^3	CO_2 (ppm)	Temp. °C	RH %
113	<0.01	22	.315	465	25	5.6
201	<0.01	5-12	.217	421	27	5.2
203	<0.01	15-23	.38	569	24	9.8
Targets	<0.05	40	1.0 (0.2 for comfort)	1000 ASHRAE	20-22	30-50

The low mid-winter relative humidities and CO_2 levels recorded in the building reflect the extremely dry outdoor conditions of Prince Albert and the high air exchange rate within the building. The use of recycled materials (e.g. kitchen and bathroom cabinetry) also contributed to the good indoor air quality due to reduced material associated pollutant emissions.

Conclusions

Based on the results of the 15-month monitoring period, the addition of interior insulation to the solid masonry walls of the building has not adversely affected the performance of the wall system. Not surprisingly, the walls that were stuccoed on the exterior resist moisture penetration better than the unprotected wall. Moisture conditions within the protected wall assemblies were relatively benign and would not adversely affect durability. Rain penetration of the one unprotected wall was marked by the detection of moisture within the assembly, the increase in the moisture content of wood framing members and higher wall cavity humidity levels. Fortunately, the wall assemblies also tend to dry out quickly afterwards. The extent to which such moisture loading represents a threat to the integrity of the masonry, mortar joints and interior wood framing is not known. Further monitoring of the building will be undertaken to track conditions over time. It should be noted that the observations and conclusions of this study are particular to Prince Albert, Saskatchewan which has relatively brief seasons associated with freeze-thaw cycles and the dry climate promotes the drying of wetted building envelope assemblies. Results may vary for buildings located in different climates.

While the presence of pollutants in the indoor air is very low, it occurs largely at the expense of energy efficiency and occupants' comfort. The building may be over-ventilated as energy costs are high and mid-winter indoor relative humidity levels are uncomfortably low. The ventilation system air flow rates could have been better rationalized based on the actual ventilation air requirements of the occupants and building. Heat recovery should also have been considered given the relatively cold climate and the continuous operation of the system.

Overall, the condition of the building has been substantially improved as a result of the renovation. Long-term durability is expected to be improved while living conditions for the occupants have been greatly enhanced.

Implications for the Housing Sector

The results of this project demonstrate that, at least in the short term, solid masonry walls in cold, dry climates are not adversely affected by the installation of interior insulation, particularly if measures are imposed to control interior and exterior moisture sources. More extensive monitoring of this building, as well as other ones, will be required to evaluate the extent to which this conclusion holds true over the longer term and in other locations. If successful, interior insulation retrofits will increase the options available to housing industry in the renovation of apartment buildings.

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Research Report: *The Renovation of an Apartment Building with Solid Masonry Walls*

Research Consultants: Dr. Robert Dumont, Larry Snodgrass and Jerry Makohon, Building Performance Section, Saskatchewan Research Council

A full report on this project is available from the Canadian Housing Information Centre at the address below.

Housing Research at CMHC

Under Part IX of the *National Housing Act*, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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